

**CLAIMS :**

1. A method of epitaxially growing a second crystal over a first crystal, the first crystal having a first lattice constant, the second crystal having a second lattice constant, the method comprising the steps of:

- 5           a) cleansing a surface of the first crystal by thermal desorption;
- b) depositing a first layer of a first material over the surface of the first crystal;
- c) depositing a second layer of a second material over the first layer; and
- d) epitaxially growing the second crystal over the second layer;

wherein the first layer substantially accommodates strain accumulated between the first crystal and the second crystal during epitaxial growth, thereby substantially preventing strain relaxation and formation of dislocation defects.

2. The method of claim 1, wherein the step a) of cleansing the surface of the first crystal by thermal desorption includes the steps of:

- 15           a1) bringing a temperature of the first crystal to  $T_s$  °C,  $T_s$  ranging from about 495°C to about 600°C;
- a2) introducing a desorption vapor having a desorption vapor pressure; and
- a3) annealing the first crystal under the desorption vapor pressure at temperature  $T_s$ ;

wherein the desorption vapor pressure is greater than a vapor pressure of the first crystal at  
20   temperature  $T_s$ .

3. The method of claim 2, wherein the desorption vapor pressure ranges from about 0.004 pa to about 0.012 pa, and wherein surface oxides of the first crystal are desorbed.

4. The method of claim 3, wherein the first crystal comprises group-III/group-V species, and the

5 desorption vapor comprises group-V species.

5. The method of claim 4, wherein the first crystal comprises GaAs, GaP, InAs or InP, and wherein the desorption vapor comprises  $As_2$  or  $As_4$  if the first crystal is GaAs or InAs, or the desorption vapor comprises InAs,  $P_2$  or  $P_4$  if the first crystal is GaP or InP.

6. The method of claim 2, wherein the step b) of depositing a first layer includes the steps of:

b1) introducing into a first vapor of the first material, wherein part of the first vapor condenses on the surface of the first crystal, thereby forming the first layer; and

b2) adjusting a thickness of the first layer by varying a temperature of the first crystal;

7. The method of claim 6, wherein the first vapor is introduced at a temperature which is less than an optimal growth temperature for epitaxy.

8. The method of claim 7, wherein the first crystal comprises group-III/group-V species, and the

first material comprises group-V species.

9. The method of claim 8, wherein the first crystal comprises GaAs, GaP, InAs or InP, and the first material comprises  $\text{As}_2$ ,  $\text{As}_4$ ,  $\text{P}_2$  or  $\text{P}_4$ .

10. The method of claim 9, wherein the thickness of the first layer ranges from approximately a

5 few Å to approximately a few tens of Å.

11. The method of claim 10, wherein the step b1) of introducing a first vapor of the first material, includes the step of opening a first shutter blocking a growth chamber from a first vapor source.

12. The method of claim 6, wherein the step c) of depositing a second layer of a second material includes the steps of:

c1) introducing the second vapor, a temperature of the first crystal being maintained at  $T_d$  within a range of about 30°C to about 250°C, wherein at least part of the second vapor condenses over the first layer;

c2) annealing the second layer by raising the temperature of the first crystal from  $T_d$  to a temperature of about 400°C to about 580°C, under a pressure of the first vapor of about 0.008 pa.

13. The method of claim 12, wherein an amount of the second vapor introduced is such that the second layer is formed by a mono-layer of atoms of the second material.

14. The method of claim 13, wherein the step c1) of introducing the second vapor comprises the steps of:

c11) providing a furnace containing a second vapor of the second material;

c12) opening a second shutter allowing the second vapor to travel from the furnace to a

5 growth chamber;

wherein the second shutter is opened for a predetermined time duration, whereby to allow a predetermined amount of the second vapor to travel from the furnace to the growth chamber, the predetermined amount of the second vapor being determined by the number of atoms of the second material necessary to form a mono-layer of said atoms over the first layer.

15. The method of claim 14, wherein the first crystal comprises group-III/group-V species, the first material comprises group-V species, and the second material comprises group-III species.

16. The method of claim 15, wherein the first crystal is selected from the group consisting of

15 GaAs, GaP, InAs and InP, the first material is selected from the group consisting of As<sub>2</sub>, As<sub>4</sub>,

P<sub>2</sub> and P<sub>4</sub>, the second material is selected from the group consisting of In, Ga and Al or any

combination thereof, and wherein the second vapor has a pressure of about  $5 \times 10^{-5}$  pa, the second

vapor has a temperature of about 780° C if the second material is In, the second vapor has a

temperature of about 900° C if the second material is Ga, the second vapor has a temperature of

20 about 1200° C if the second material is Al.

17. The method of claim 16, wherein for the second material, combinations of Ga, Al, and In, are in a relative ratio substantially equal to the ratio of elements forming the second crystal which is to be epitaxially grown.

18. The method of claim 16, wherein the second shutter is opened for a time duration ranging from about 1 second to about 3 seconds.

19. The method of claim 18, wherein a number per surface area of group-III atoms forming the mono-layer is about  $6.5 \times 10^{14} \text{ cm}^{-2}$  and wherein the second shutter is opened for 2.2 seconds.

20. The method of claim 16, wherein the thickness of the first layer ranges from a few Å to a few tens of Å.

21. The method of claim 12, wherein the second crystal is a group-III/group-V crystal and wherein the step d) of epitaxially growing the second crystal includes the steps of:

d1) introducing group-III species into a growth chamber;

d2) introducing group-V species into the growth chamber;

d3) maintaining a temperature inside the growth chamber near an optimal temperature for epitaxial growth of the second crystal.

22. The method of claim 21, wherein the group-V species is introduced by opening a first shutter

whereby to let a group-V flux into the growth chamber, and the group-III species is introduced by opening a second shutter whereby to let a group-III flux into the growth chamber.

23. The method of claim 22, wherein the ratio of the group-V flux to the group-III flux is

5 substantially in the range of about 1.5 to about 3.

24. The method of claim 23, wherein the second crystal is selected from the group consisting of

InAs,  $\text{In}_x\text{Ga}_{1-x}\text{As}$ ,  $\text{In}_x\text{Al}_{1-x}\text{As}$  or GaP.

0 25. The method of claim 1, wherein the method is used to manufacture semiconductor devices.

26. The method of claim 25, wherein the method is used in microelectronic and optoelectronic applications.

15 27. A method of preparing a substrate for subsequent epitaxial growth of a crystal over the substrate, the method comprising the steps of:

- a) cleansing a surface of the substrate by thermal desorption;
- b) depositing a first layer of a first material over the surface of the substrate; and
- c) depositing a second layer of a second material over the first layer.

20 28. The method of claim 27 wherein the first layer accommodates strain accumulated between the

substrate and the crystal during epitaxial growth, thereby preventing strain relaxation and formation of dislocation defects.

29. The method of claim 28 wherein:

- 5           the substrate comprises group-III/group-V species;
- the crystal comprises group-III/group-V species;
- the first material comprises group-V species; and
- the second material comprises group-III species.

10       30. The method of claim 29, wherein the first layer has a thickness within a range of approximately a few Å to a few tens of Å.

31. The method of claim 30, wherein the second layer is a monolayer of group-III atoms.

15       32. A method of preparing a GaAs substrate for subsequent epitaxial growth of a InAs layer over the substrate, the method comprising the steps of:

          a) extracting surface oxides from a surface of the substrate by thermal desorption, the thermal desorption including the steps of:

- a1) heating the substrate to a temperature of about 600°C; and
- 20       a2) annealing the substrate for about 10 minutes under a pressure of As<sub>2</sub> vapor of about 0.008 pa;

b) depositing a condensed layer of  $\text{As}_2$  on the surface of the substrate, depositing a condensed layer including the steps of:

b1) lowering the temperature of the substrate to about  $110^\circ\text{C}$  while subjecting the substrate to an  $\text{As}_2$  vapor pressure of about 0.008 pa, whereby a condensed layer of  $\text{As}_2$  is formed on the surface of the substrate; and

b2) adjusting the thickness of the condensed layer of  $\text{As}_2$  by raising the temperature of the substrate to about  $250^\circ\text{C}$ , thereby thinning the condensed layer of  $\text{As}_2$  to several tens of Å; and

c) depositing a mono-layer of In atoms over the condensed layer of  $\text{As}_2$ , the depositing a mono-layer comprising the steps of:

c1) introducing In vapor at a temperature of about  $790^\circ\text{C}$ , the temperature of the substrate being maintained around  $250^\circ\text{C}$  and being subjected to an  $\text{As}_2$  vapor pressure of about 0.008 pa; and

c2) raising the temperature of the substrate to about  $400^\circ\text{C}$  while the  $\text{As}_2$  vapor pressure is maintained around 0.008 pa, thereby annealing the mono-layer;

wherein upon completion of the step c), conditions are propitious for epitaxial growth of the InAs layer, and wherein the epitaxial growth substantially does not introduce dislocation defects caused by lattice mismatch between the GaAs substrate and the InAs layer.

33. The method of claim 32, further comprising the step d) of epitaxially growing the InAs layer,



the step d) including the steps of:

d1) introducing a flux of In vapor;

d2) introducing a flux As vapor; and

d3) maintaining the temperature of the substrate between about 400°C and about 450°C;

5 wherein the ratio of the flux of As vapor to the flux of In vapor is maintained at about 2.5.

34. A semiconductor device comprising:

a first layer of a first material;

a second layer of a second material disposed over the first layer;

10 a third layer of a third material disposed over the second layer; and

a fourth layer of a fourth material disposed over the third layer;

wherein the fourth layer is epitaxially grown, and wherein the second layer substantially accommodates strain accumulated between the first material and the fourth material during epitaxial growth of the fourth layer, thereby substantially preventing strain relaxation and  
15 formation of dislocation defects.

35. The semiconductor device of claim 34, wherein:

the first material is a group-III/group-V material;

the second material is a group-V material;

20 the third material is a group-III material; and

the fourth material is a group-III/group-V material.

36. The semiconductor device of claim 35, wherein:

the first material is selected from the group consisting of GaAs, GaP, InAs and InP;

the second material is selected from the group consisting of As<sub>2</sub>, As<sub>4</sub>, P<sub>2</sub> and P<sub>4</sub>;

5 the third material is selected from the group consisting of In, Ga and Al or any combination thereof; and

the fourth material is selected from the group consisting of InAs, In<sub>x</sub>Ga<sub>1-x</sub>As, In<sub>x</sub>Al<sub>1-x</sub>As

or GaP.

37. The semiconductor device of claim 36, wherein:

the second layer has a thickness ranging from a few Å to a few tens of Å; and

the third layer is substantially a mono-layer of atoms.

38. The semiconductor device of claim 37, wherein:

15 the first material is GaAs;

the second material is As<sub>2</sub>;

the third layer is a mono-layer of In atoms; and

the fourth material is InAs.